Magnetic depth profiles of complex oxide thin films

Scientific Achievement

In order to explore the competition between superconductivity and magnetism on the nanometer scale, we have studied epitaxial heterostructures of superconducting $YBa_2Cu_3O_{7-\delta}$ layers and ferromagnetic $La_{0.7}Ca_{0.3}MnO_3$. In this system a new large magnetoresistance (MR) effect was observed during the superconducting transition of $YBa_2Cu_3O_{7-\delta}$, which did not occur at temperatures above this transition. Our polarized neutron reflectometry experiments were able to conclusively correlate the occurance of this MR to an antiferromagnetic alignment between two adjacent $La_{0.7}Ca_{0.3}MnO_3$ layers. Absence of the MR effect, but not of the antiferromagnetic alignment, above the transition indicates that the effect is related to the superconducting state of $YBa_2Cu_3O_{7-\delta}$. In a second series of samples, magnetization measurements had shown a significantly reduced magnetization of the $La_{0.7}Ca_{0.3}MnO_3$ layers even well above the critical temperature of $YBa_2Cu_3O_{7-\delta}$. Our polarized neutron reflectometry experiments were able to prove that this reduction was not the result of an overall decreased moment, but that the magnetization was distributed inhomogenously over the ferromagnetic layer [*A. Hoffmann et al., Phys. Rev. B* ***72****, (2005) 140407(4) (R)*]. While the magnetization remained high at the center of the layer, in the regions close to the interface it was found to be close to zero.

Significance

High quality epitaxial heterostructures consisting of complex oxide materials are proving to be a promising new class of materials, showing many interesting phenomena. They allow the combining of the wide range of diverse physical properties that these oxides can have (e.g., ferromagnetism, antiferromagnetism, superconductivity), which furthermore can be modulated by doping. Examples of current research issues are exchange bias, exchange coupling, and interactions between ferromagnets and superconductors. While some of the physical properties should be similar to those in metallic systems, there can be distinct differences. In complex oxides, variations of the chemical or electronic composition can change these physical properties close to the interface. In order to determine whether or not these variations are inherent to the complex oxide materials used or simply growth-related, it is important to do detailed measurements of the interfaces. Polarized neutron reflectometry is an essential tool for investigating the magnetic structure in these heterostructures This is illustrated by our work on $YBa_2Cu_3O_{7-\delta}/La_{0.7}Ca_{0.3}MnO_3$ superlattices [*V. Peña et al., Phys. Rev. Lett.* ***94*** *(2005) 057002(4)*], where these experiments allowed the detailed determination of the chemical and magnetic profile of individual layers in the system, which is key in understanding the physical properties

Performers

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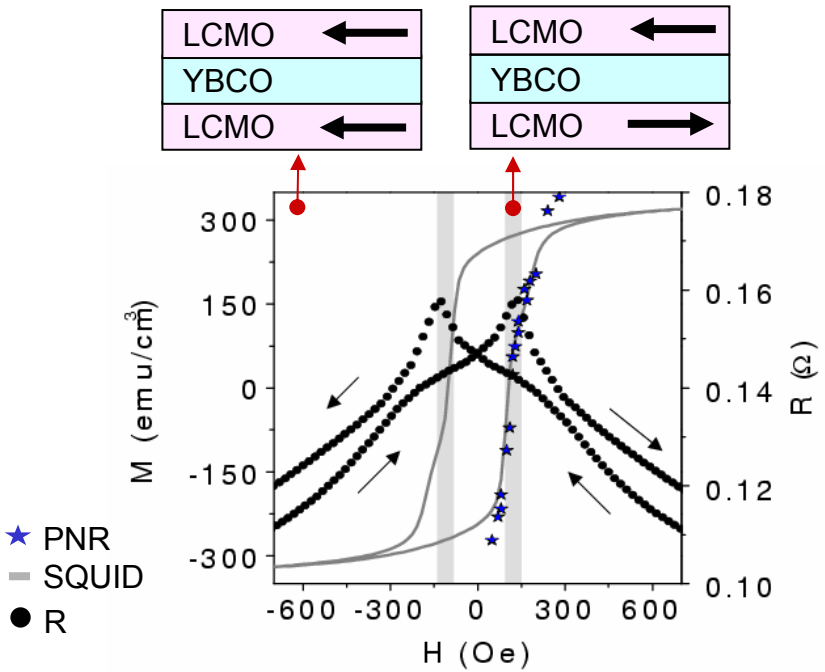
Magnetic depth profiles of complex oxide thin films

- Complex oxides have wide range of physical properties, tunable with doping.
- Epitaxial heterostructures can test interplay between different phenomena.
- **Polarized Neutron Reflectometry** is the ideal tool to address issues such as:

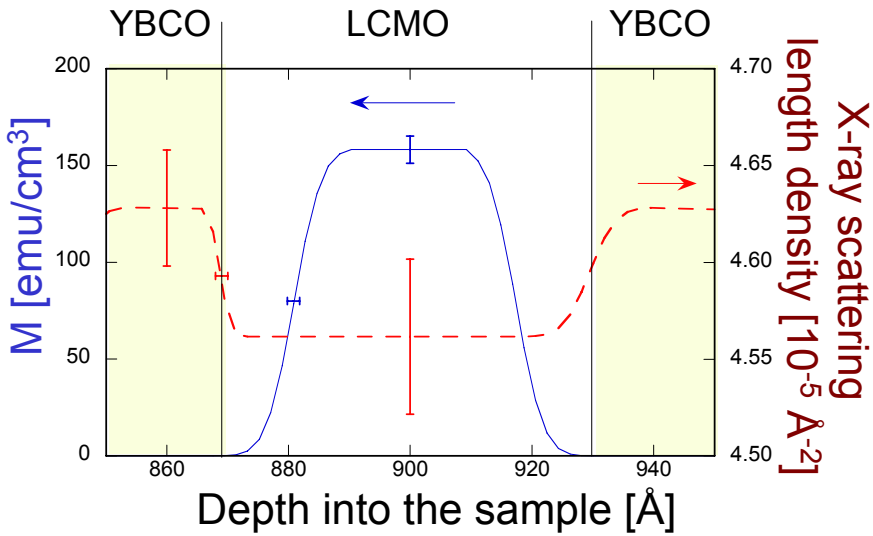
New GMR when $T \leq T_c$



=> AF alignment of LCMO layers

Indicates spin injection into superconductor

Reduced magnetization in $YBa_2Cu_3O_{7-\delta}/La_{0.7}Ca_{0.3}MnO_3$ superlattices



=> Suppressed magnetization at interface

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